



# Office of Naval Research

## *Tropical Cyclone Field Program Updates FY21 Recap/FY22 Plans*

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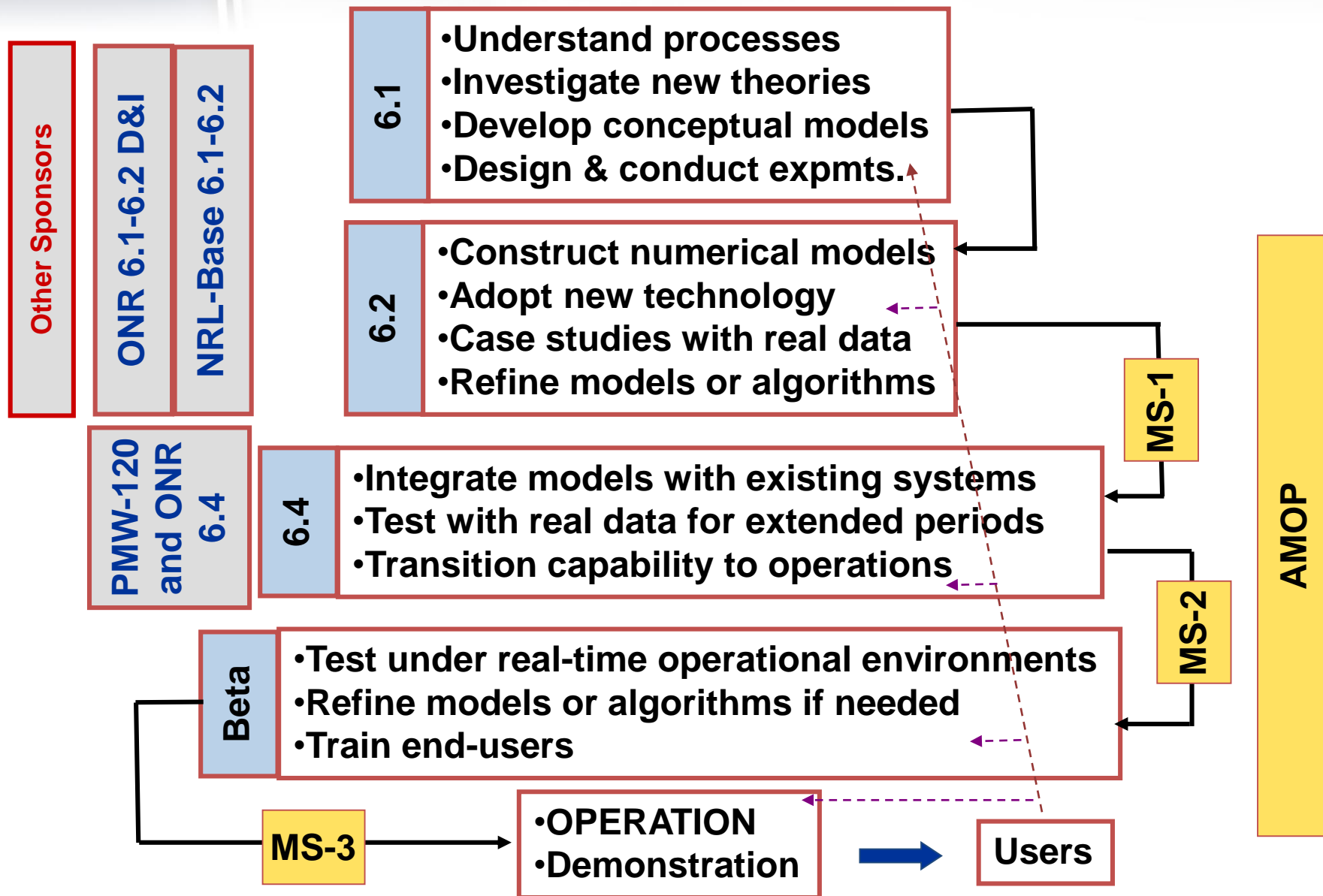
***2022 TCORF/76<sup>th</sup> IHC – 9 March 2022***



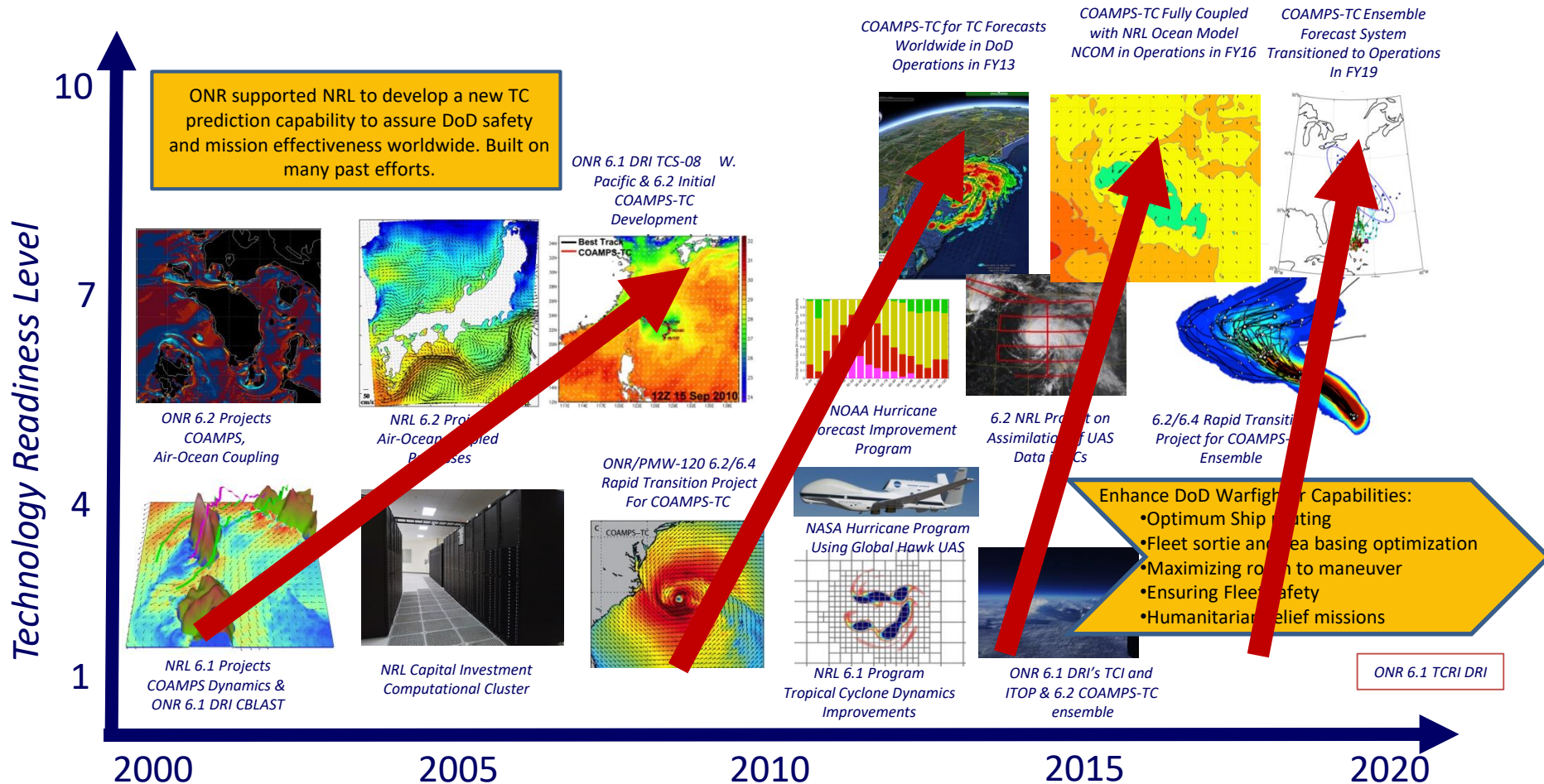
# Outline

- **Overview of ONR TC research paradigm**
- **FY20-24 Tropical Cyclone Rapid Intensification (TCRI)**
  - **[6.1]** *An ONR Departmental Research Initiative (DRI) is a competitive, focused 3-5 year effort to advance basic scientific understanding on an environmental topic internal to ONR Code 32.*
- **FY21-24 Predicting Hurricane Coastal Impacts**
  - **[6.1-6.2]** *A National Oceanographic Partnership Program (NOPP) is a partnership between federal agencies, academia, and industry to advance ocean science research and education.*
- **FY20-22 Probabilistic Surge and Inundation Prediction System (PSIPS)**
  - **[6.2]** *An ONR Technical Candidate (TechCan) is applied research or technology development in areas with strong path to field. Follow-on Future Naval Capability (FNC) work involves field maturation, system integration, etc.*

# ONR Marine Meteorology: Vertically Integrated R2O

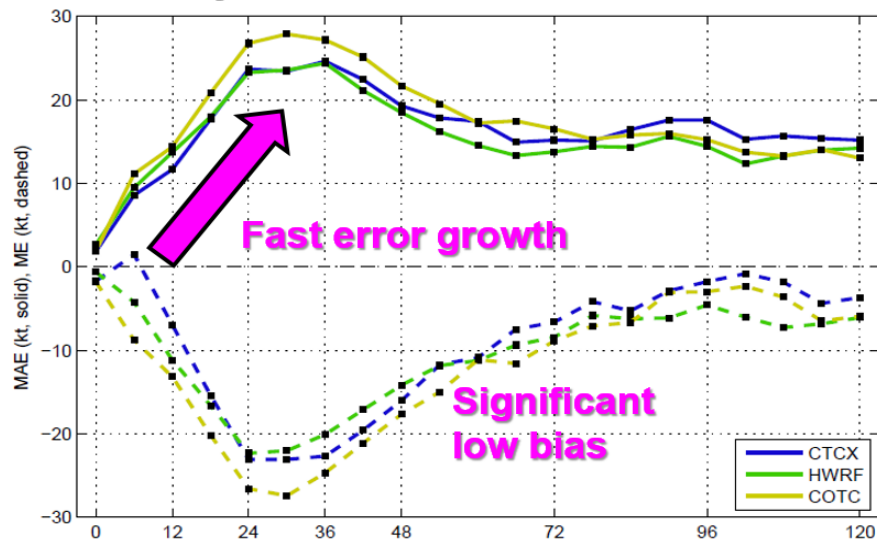


# ONR Marine Meteorology Success Story: Tropical Cyclone Prediction

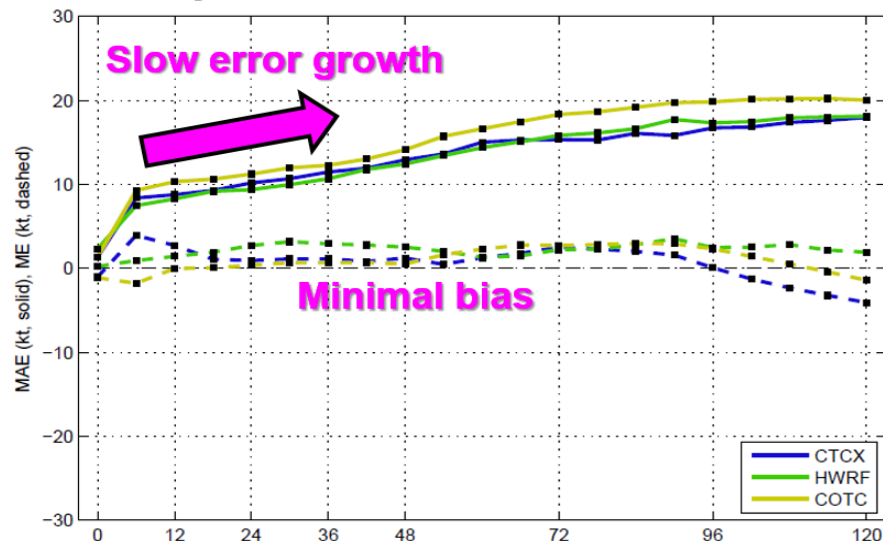


# Tropical Cyclone Rapid Intensification (TCRI) Program Overview

Intensity MAE and ME: **Observed RI 0-24 h**



Intensity MAE & ME: **No observed RI 0-24 h**



- Identify the key processes and predictability barriers governing the rapid intensification of tropical cyclones. Particular focus on:
  - Onset of RI
  - Boundary layer and cloud microphysics (including diabatic heating) processes
- Field measurements conducted in close collaboration with NOAA IFEX (2020) and APHEX (2021+)
- Holistic use of high-resolution numerical modeling, data assimilation systems and tools (ensembles-adjoints), LES
  - Improve the Navy's tropical cyclone model (COAMPS-TC) and products to more accurately predict TC RI
- Special analysis of satellite remote sensing (including SAR) and machine learning methods



# Tropical Cyclone Rapid Intensification (TCRI) 2021 Field Experiment

- Conducted in close collaboration with NOAA APHEX
- 2 P-3 Flights during Ida and Sam and collaborative P-3 & G-IV flights in 4 storms
- Added flight modules for several other storms
- Deployed 257 additional dropsondes and 101 AXBTs in support of TCRI objectives

## 2021 Aircraft Missions tasked by HRD & ONR/HRD (4 P-3, 7 G-IV)

- 20210814N1 (Grace)
- 20210815N1 (Grace)
- 20210818N1 (Grace)
- **20210827H1 (Ida)**
- 20210829H1 (Ida)
- 20210905N1 (Larry)
- 20210906I1 (Larry)
- 20210906N1 (Larry)
- 20210907N1 (Larry)
- **20210925H1 (Sam)**
- 20210925N1 (Sam)

## 2021 ONR dropsondes / NRL AXBTs deployed:

- Fred: 6 / 0
- Grace: 84 / 11
- Henri: 17 / 20
- Ida: 66 / 26
- Larry: 1 / 8
- Sam: 83 / 36
- **Total: 257 / 101**

## ONR/NRL Expendables

### ONR Dropsondes

- 2021 beginning of season: 356
- 2021 usage: 257
- Current balance: 99

### NRL AXBTs:

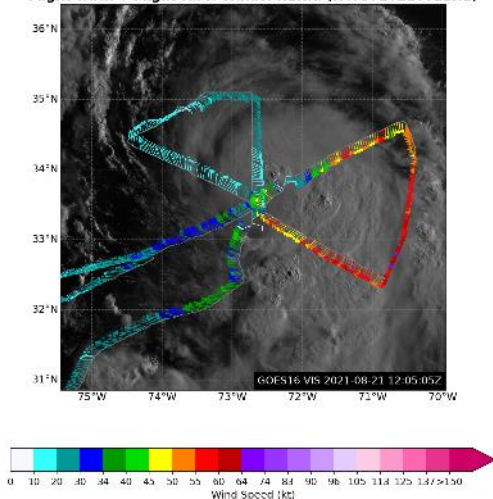
- 2021 beginning of season: 144
- 2021 usage: 101
- Current balance: 43

# Tropical Cyclone Rapid Intensification (TCRI) 2021 Field Experiment

## Gravity Wave and Microphysics Modules

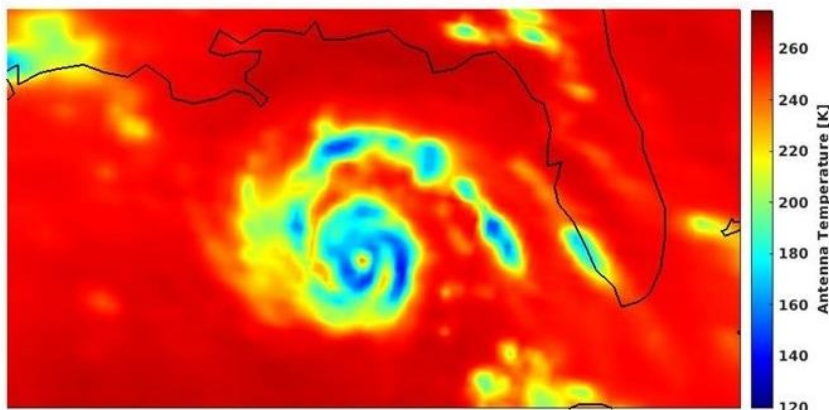
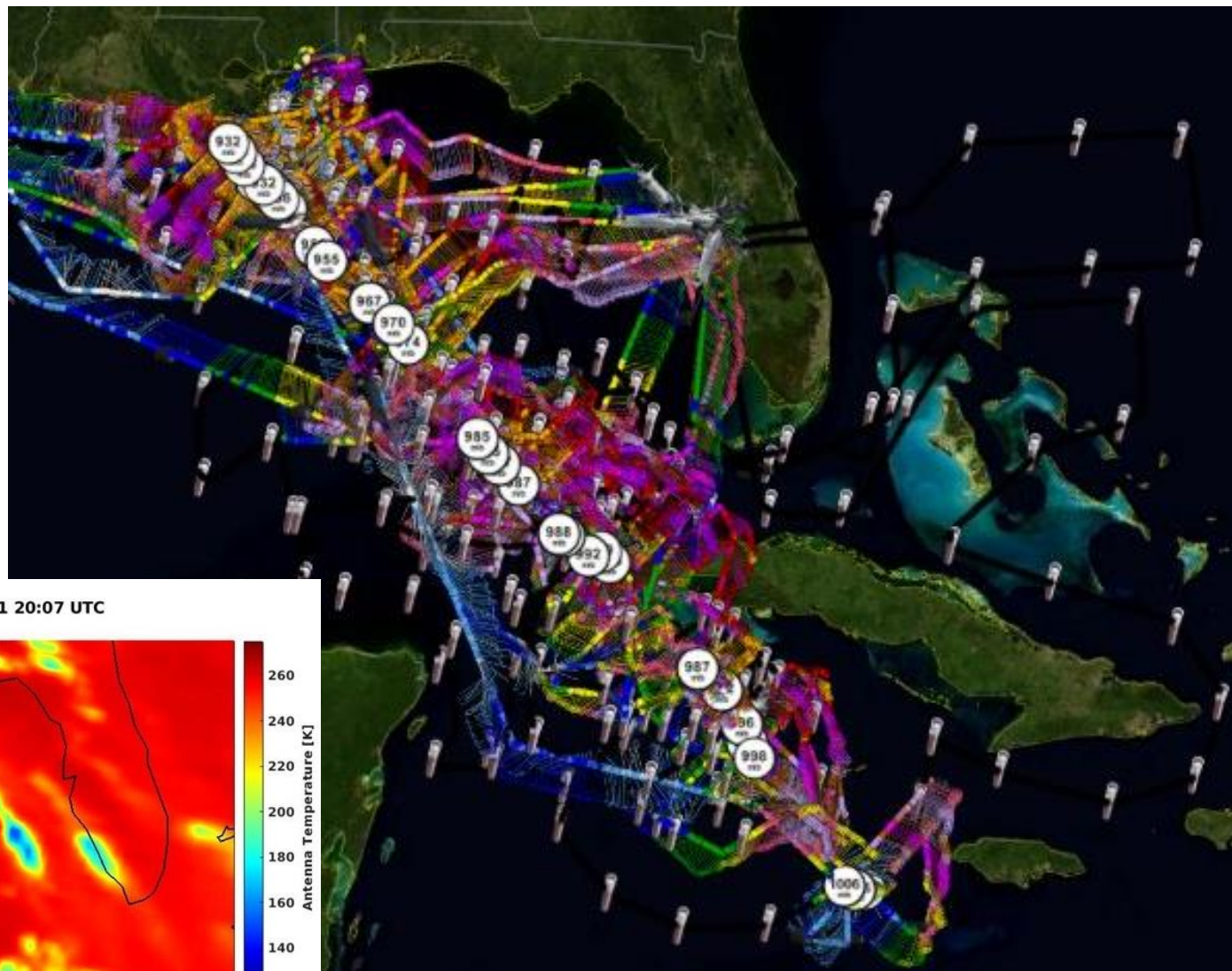
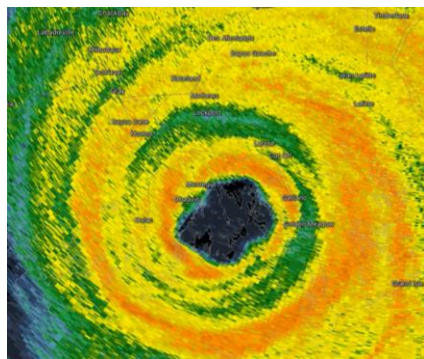
*Henri: 20210821H1*

Flight track + Flight-level Winds: HENRI (NOAA 20210821H1)



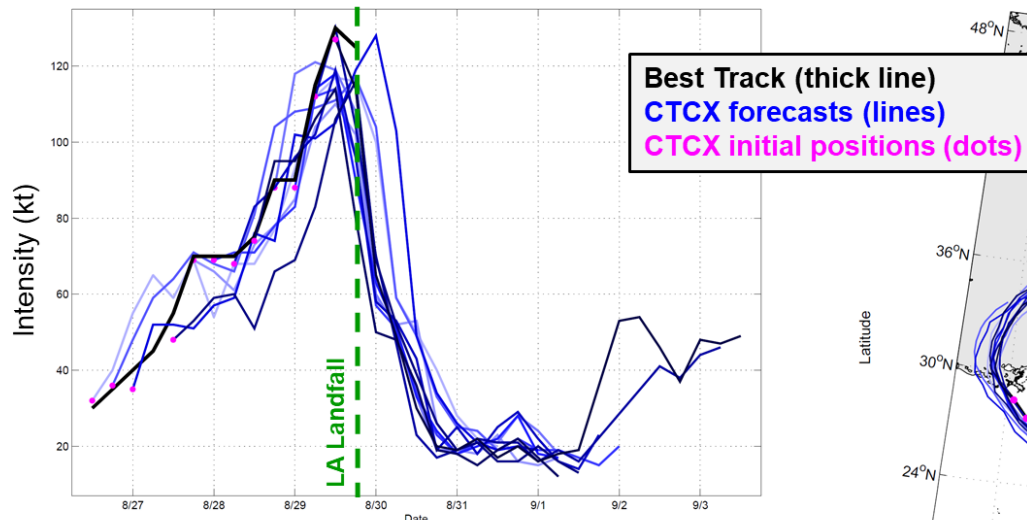
# Tropical Cyclone Rapid Intensification (TCRI) 2021 Field Experiment

## Ida Coverage



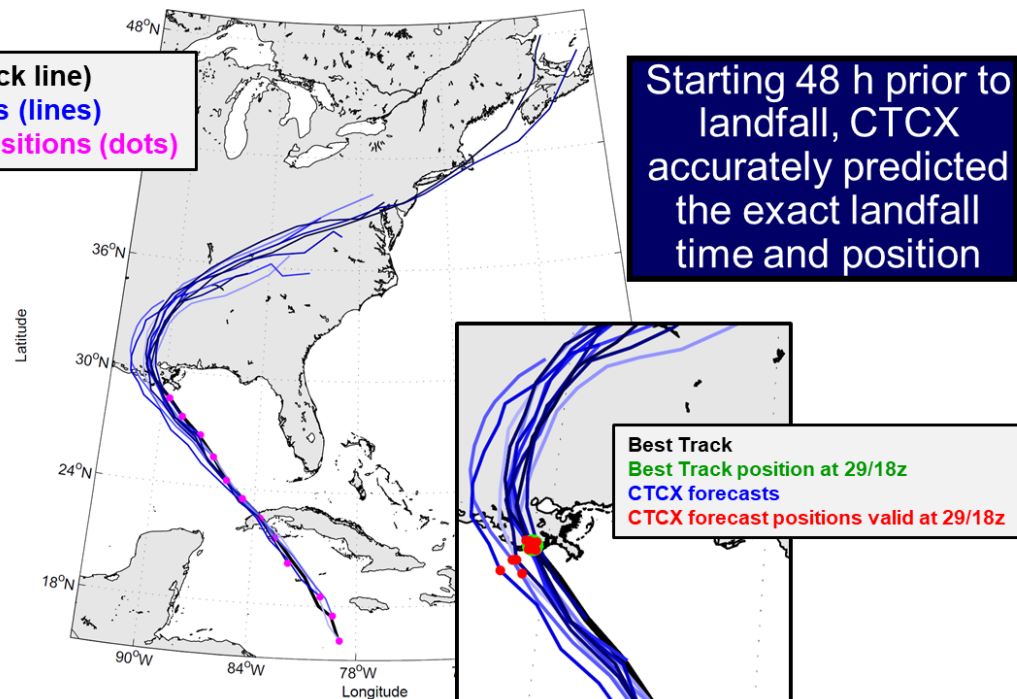
# Tropical Cyclone Rapid Intensification (TCRI) COAMPS-TC Performance on Ida (09L)

**Intensity**



All CTCX forecasts indicated a peak intensity of at least 110 kt just prior to landfall, even when the initial intensity was just 30 kt

**Track**



CTCX RI and track forecasts for Hurricane Ida (13L) were amazingly accurate, very similar to those for Hurricane Laura (2020)



# Tropical Cyclone Rapid Intensification (TCRI) 2020-21 Lessons Learned

- **What went well:**

- Virtual TCRI program
  - Google Meets and other virtual tools to support interactions during missions
  - Rotating list of science directors, forecasters, and support
- TCRI-APHEX collaboration
  - Adding dropsondes to collaborative P-3 and G-IV flights
  - Flight planning including tack-on modules
    - GW module, Microphysics spiral, Boundary layer module
  - Dedicated TCRI flights
- NRL adjoint and Ryan Torn's targeting for G-IV missions

- **What could have gone better:**

- Virtual TCRI program
  - COVID protocols, lack of an in-person team meeting
  - Broader and less focused program level goals
- Ease of high level resource/logistics coordination (interagency funding)
- Need for better/quantitative decision criteria for earlier sampling

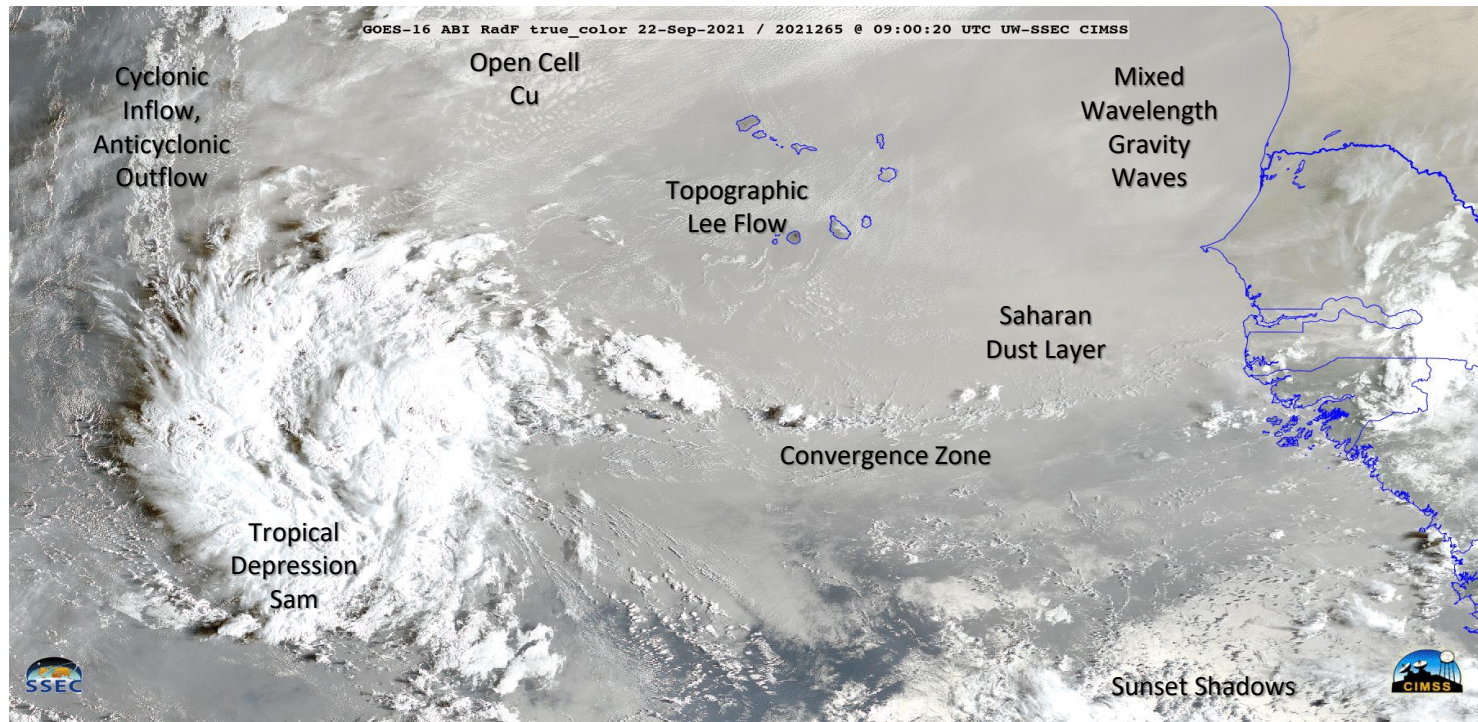


# Tropical Cyclone Rapid Intensification (TCRI) 2022 Plans

- **Continue to work closely with interagency partners**
  - WATL: P-3 Flights (& G-IV) in collaboration with NOAA APHEX
- **Continue augmentation of logistics, contributions to resource sharing**
  - Additional dropsondes available for the P-3 and G-IV
  - Option for additional flight modules and collaborative flights
  - NRL will send more AXBTs to AOC (need to confirm)
  - Open to cost sharing research on new instruments with robust technological capabilities and new science potential
- **Continue scientific focus on:**
  - Onset of RI (may include genesis via CPEX collaboration)
  - Boundary layer and microphysics processes
  - Sheared storms that undergo RI
- **Prior to Field Campaign:**
  - Objectively quantify how many expendables needed to support science goals
  - With the higher quality AXBTs, we should try to clearly define what regions of the storm are the highest priority
  - More team involvement in mission planning - we want the whole team to make sure their science objectives are being met

# Tropical Cyclone Rapid Intensification (TCRI) 2022 Plans

- **Expand successful collaboration formula with NOAA**
  - EATL: DC-8 flights in collaboration with NASA CPEX
  - Currently determining additional flight hours, dropsondes, and instrumentation
- **Moisture and Aerosol Gradients/Physics of Inversion Evolution (MAGPIE) DRI call for planning letters coming soon:**
  - <https://www.onr.navy.mil/en/Science-Technology/Departments/Code-32/all-programs/marine-meteorology-space>



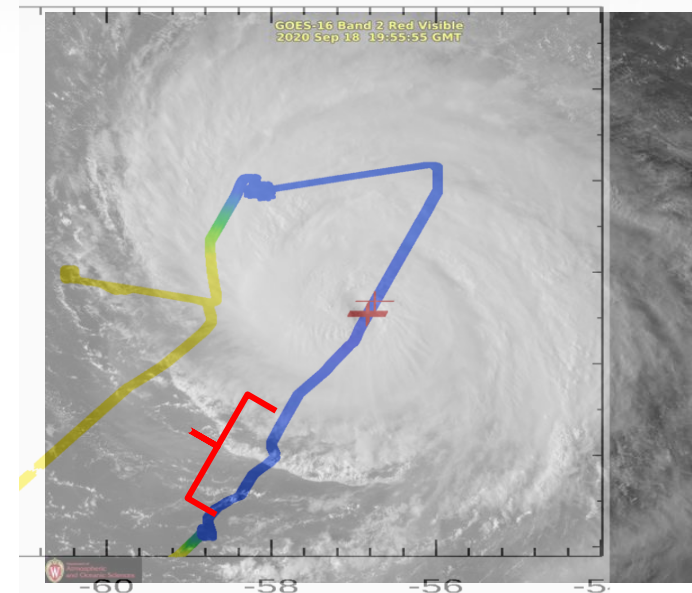
# TCRI Summary and Plans

TCRI will build on key findings from previous ONR field campaigns at the air-sea interface (CBLAST), at the tropopause (TCI-15), and through the atmospheric column (TCS-08, ITOP) by focusing on:

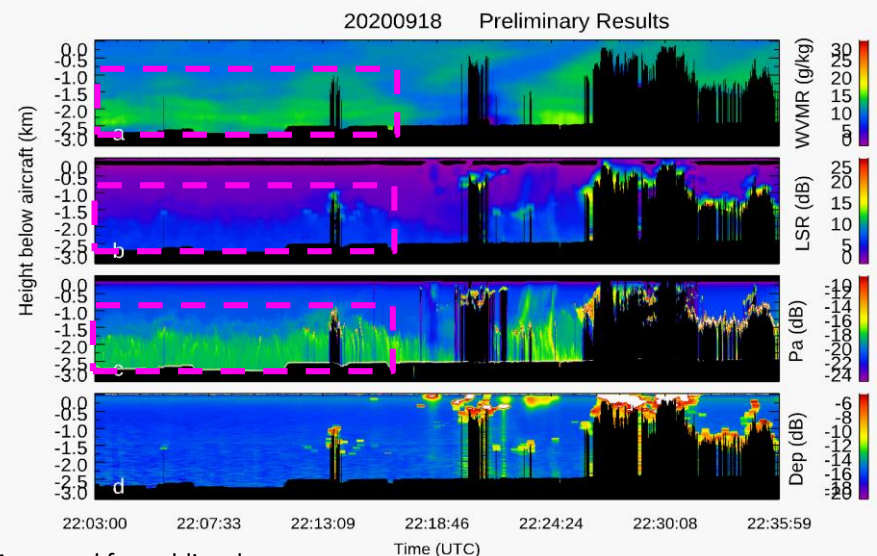
- ✓ Onset of RI
- ✓ Boundary layer and microphysics processes
- ✓ Sheared storms that undergo RI

Goal is to sustain and expand collaboration with government partners in 2022 season:

- ✓ Continue to have TCRI PIs work closely with NOAA HRD and APHEX program
- ✓ Options for additional flight modules
- ✓ Additional microphysics legs if possible
- ✓ Should have additional dropsondes available for the NOAA P-3 and G-IV
- ✓ Providing support Raman Lidar observing (right)
- ✓ Work with NASA CPEX program to support additional science in Cabo Verde in September



**Quantify MABL properties around TC**



# Predicting Hurricane Coastal Impacts

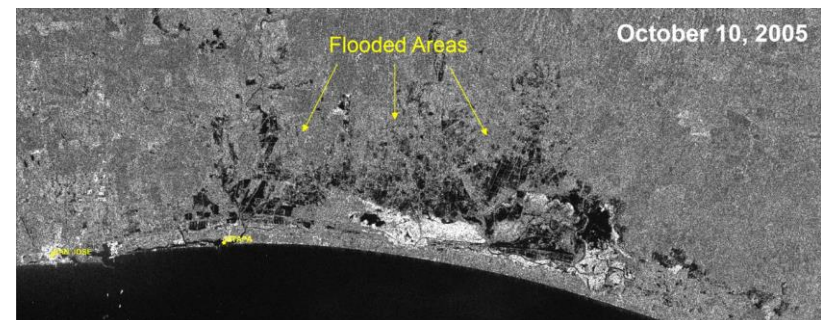
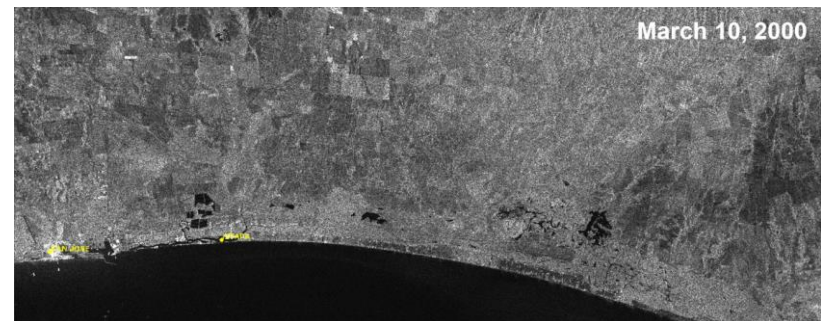
FY21-24 NOPP (PO: Reggie Beach, ONR 322LO)

## BACKGROUND:

Over the last 4 years, community coastal wave, current and sediment transport models have been used in a hindcasts of CONUS landing hurricanes. These hindcasts (forced by the modeled best-track winds) were evaluated quantitatively, including the ability to **reproduce wave heights and water levels, and the observed changes on land (erosion, accretion and breaching)**. The results indicate that *if the forecast winds and track are correct, the greatest uncertainties in the coastal impacts are not in the numerical models, but on land, in terms of boundary conditions for elevation, sediment type, vegetation, infrastructure and buildings.*

## SCOPE OF PROJECTS:

- Task 1) Year 1, the building of a Digital Elevation Model (DEM) and in Years 2-4 regular updates and quantitative post-hurricane impact summaries;
- Task 2) New quantitative capabilities in satellite remote sensing for both building a ground-truth DEM and quantitative geophysical measurements during the storms, for comparison to and possible assimilation into model forecasts; (*see right figures*)
- Task 3) In situ measurements to include offshore waves, and both offshore and inland water levels, for assimilation prior to landfall and ground truth evaluations afterward; and
- Task 4) Forecasting of wave, surge, sediment transport (erosion and accretion above and below mean sea level), structure interaction and damage.



# Request for Aircraft Collaboration

FY21-24 Coastal TC NOPP (PO: Reggie Beach)

## FIELD EFFORT:

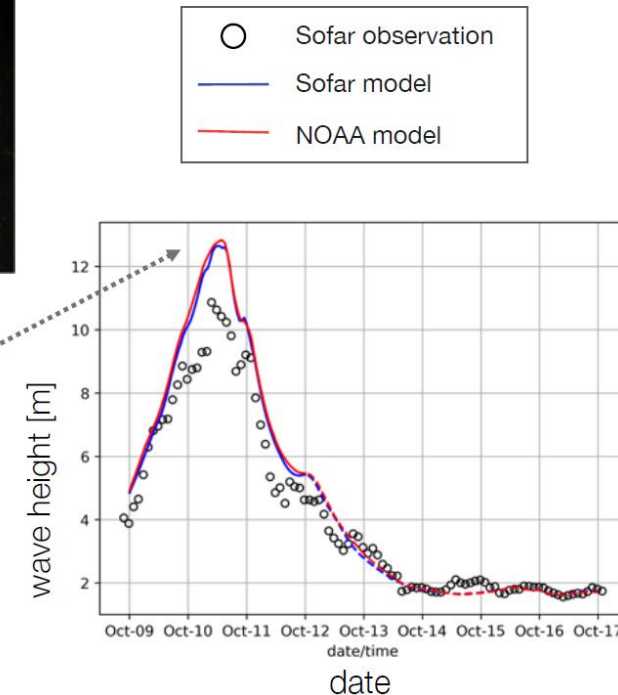
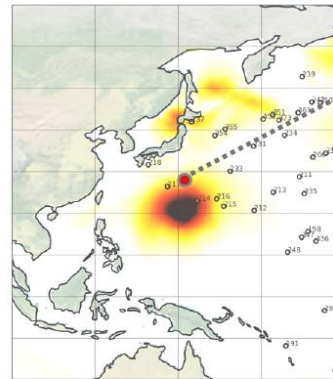
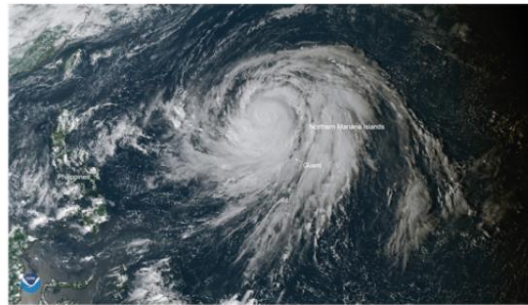
Goal: During each of the CY 2022-24 TC seasons, provide a single daily forecast of hurricane coastal impacts (see below), beginning five days prior to landfall, for three named hurricanes per season. Data collected after the event (bathymetry/topography, inundation, erosion, accretion, infrastructure & structure damage) will quantify the abilities of the model to forecast the coastal response.

## REQUEST:

Opportunity to fly and drop directional wave buoys about 3 days ahead of potential landfall for 3 storms per season *if flights of opportunity can be coordinated.*

## TASK 3: Airborne deployment of in-situ directional wave buoys

There are two funded groups to throw directional wave buoys+ out of C-130's, P-3's, or *anything willing to fly*. If there is interest and availability for flight support, this double capacity could be used in both the Atlantic and West Pacific basins. Strategy is to alternate the teams (they are funded for 3 hurricane seasons, 3 hurricanes each season). There will be a total of 18 deployments.

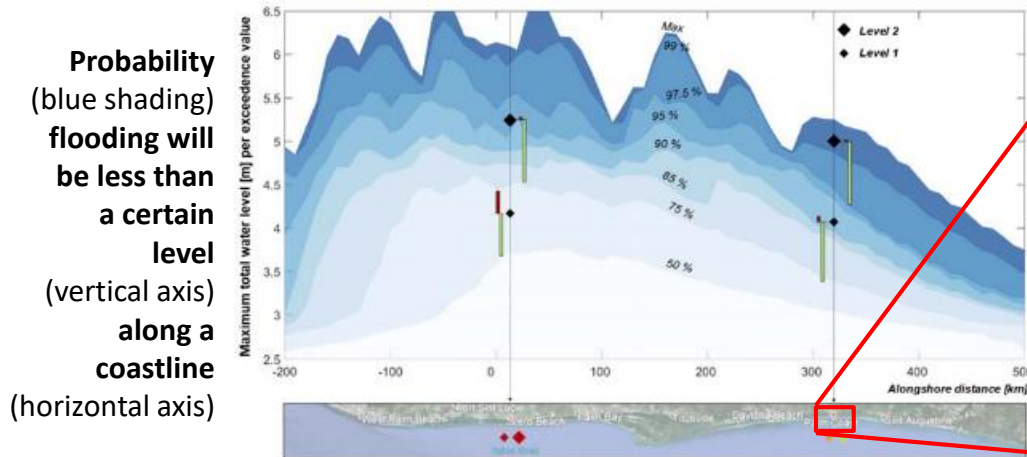


# Probabilistic Surge and Inundation Prediction System (PSIPS)

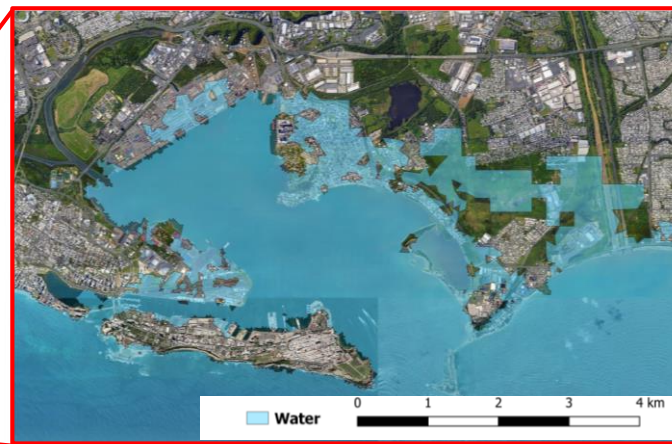
FY20-22 Technical Candidate (PO: Bill Schulz, ONR 322FMC)

## OBJECTIVE:

Develop an automated system using state-of-the-art remote sensing methods, hydrodynamic models, and visualization tools to produce forecasts of the **probability of a water level rise along a coastline** and **maps of the predicted total water level flooded inland** resulting from the passage of a tropical cyclone.



Spatial extent of inland flooding



## TECHNICAL APPROACH:

- Include neglected wave-driven processes and varying bottom roughness into hydrodynamic model
- Develop and automate remotely sensed method to provide pseudo-topography and bathymetry at a resolution necessary for accurate surge & inundation predictions
- Develop an automated ensemble system to cover the spread of known uncertainty in the winds, bathymetry, and roughness in a real-time forecast

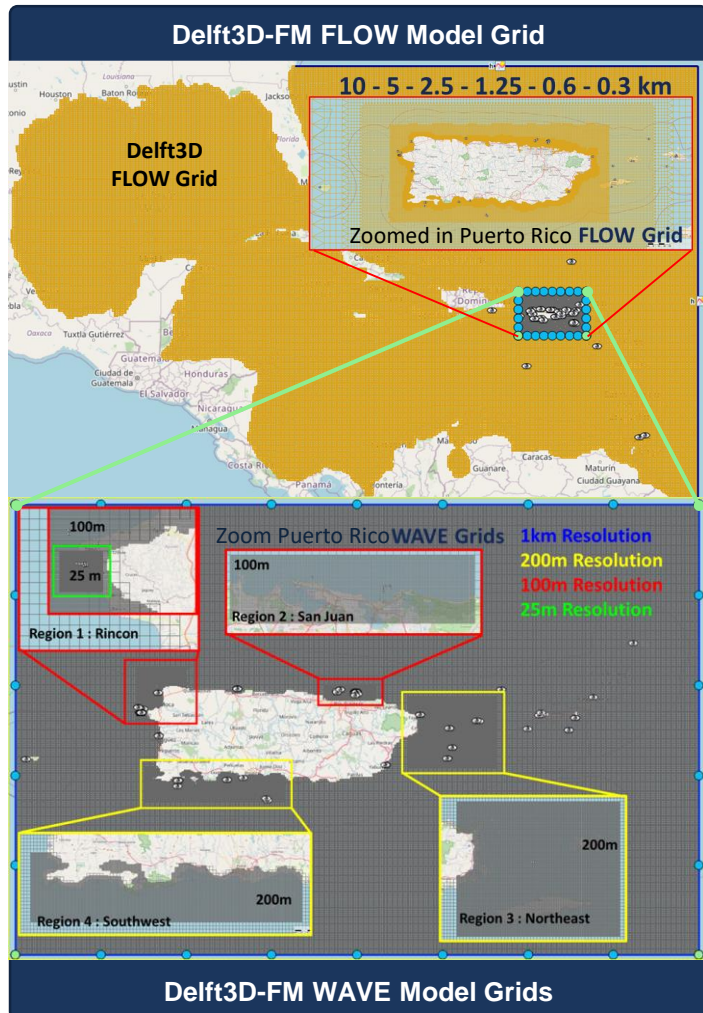
# PSIPS Accomplishments and Current Tasks

## RECENT ACCOMPLISHMENTS:

- Comprehensive model study found waves (not included in present system) are the dominant contribution (75-100%) to the total water level for steep reef-lined coasts (versus 10-20% for mildly sloping coasts)
- Built framework for coupled wave/circulation system to run in Puerto Rico to validate with observations of three hurricanes
- Scripted automation of input files for ensemble simulations based on the JTWC track forecasts and developed forecast skill and uncertainty estimate tools

## ONGOING TASKS:

- Build coupled ensemble system including effects from full wave spectrum and optimize for operational use
- Use remotely sensed algorithms to include reef locations, shelf slope, and bottom roughness as initial model inputs
- Build prototype system in Guam
- Revamp Navy Storm Surge working group and work with FNMOC to ensure effective future system transition





# Summary of Current/Future Efforts

- Tropical Cyclone Rapid Intensification (TCRI) DRI
  - ✓ Productive collaboration with NOAA in 2020 and 2021 hurricane seasons.
  - ✓ Plan to continue into 2022 by supporting additional flight hours, modules, dropsondes, and investigator time.
  - ✓ Additional partnership with NASA CPEX for DC-8 Cabo Verde activities in September.
  - ✓ Interested in discussion potential for additional partnerships.
  - ✓ Contact: Josh Cossuth, [joshua.h.cossuth.civ@us.navy.mil](mailto:joshua.h.cossuth.civ@us.navy.mil)
- NOPP Program: Predicting Hurricane Coastal Impacts
  - ✓ <https://www.nopp.org/2020/predicting-hurricane-coastal-impacts-fy21-24/>
  - ✓ Kicked off summer of 2021, project to last through 2024.
  - ✓ Plan to drop buoys along the US coast – looking for operational partners to drop from C-130, P3 and USCG helo flights. Would like to coordinate with PACOM for flights of opportunity to deploy ahead of typhoons.
  - ✓ Contact: Reggie Beach, [reginald.a.beach.civ@us.navy.mil](mailto:reginald.a.beach.civ@us.navy.mil)
- Probabilistic Surge and Inundation Prediction System (PSIPS)
  - ✓ Expanding modeling system to better account for full wave spectrum using remote sensing and state of the art hydrodynamic modeling for coastal surge probabilities.
  - ✓ If approved for follow-on program work, near-realtime demo for Guam could come in FY23
  - ✓ Contact: Bill Schulz, [william.j.schulz4.civ@us.navy.mil](mailto:william.j.schulz4.civ@us.navy.mil)